CASTING MOLD FOR ENGINE BLOCK

FIELD OF THE INVENTION

[0001] The present invention relates to molds used to produce castings that require cylindrical objects to be embedded in the casting, and in particular to casting molds for engine blocks with cast-in cylinder liners.

BACKGROUND OF THE INVENTION

[0002] The inner walls of the cylinder bores of internal combustion engines are required to withstand the abrasive action of the piston and its seal rings. In models with cast iron engine blocks, the cast iron provides the required resistance. In other models, including some V-engine blocks in which aluminum or other lightweight material is used, cylinder liners are inserted in the bores to provide adequate wear resistance.

[0003] In many engine block casting processes, cylinder liners are an integral part of the casting process and are assembled into the mold before molten metal is introduced into the mold cavity to form the engine block. After casting, when the mold is removed, these cast-in liners are permanently embedded within the cast metal walls of the cylinder bores. To improve the mechanical contact between the cylinder liners and the walls of the cylinder bores and avoid imperfections that are caused by thermal variations between the cylinder liners and the molten metal, the cylinder liners are sometimes pre-heated using, for example, induction heaters.

[0004] In a sand casting process, often referred to as the Precision Sand Process, an expendable mold package or package subassembly 40, shown in FIG. 1, is assembled from various mold segments and mold cores 44 that are combined to define, together with the cast-in cylinder liners 46, the internal and external surfaces of the engine block. The mold segments and mold cores are made of resin-bonded sand. Proper positioning of the liners in the mold and prevention of migration of the liners during pre-heating and casting presents an ongoing challenge.

[0005] Some attempts to address this problem provide that chamfered cylinder liners remain seated on corresponding chamfered seat surfaces of the mold cores during thermal expansion. The prior art provides for chamfered surfaces that are inclined with respect to a plane perpendicular to the bore axis at specific angles that are calculated to ensure that the liners remain seated and in contact with seat surfaces during pre-heating and casting. These angles are calculated using nominal (theoretical) dimensions for the length and radius of the cylinder liners and assume uniform in-situ thermal expansion of the liners. In practice, these ideal conditions are not met and the variation can cause the cylinder liners to exert force against the constraining mold seats. As a result, the mold seats will move relative to one another and/or the resin-bonded sand will fracture or crush, contaminating the mold. Either of these unintended consequences is undesirable and potentially more catastrophic than a small amount of cylinder liner migration.

[0006] Therefore, improved casting molds with cast-in cylinder liners are still needed.

SUMMARY OF THE INVENTION

[0007] One embodiment of the invention provides a casting mold for an engine block. The casting mold includes a first mold seat with a double-curved surface, and a cast-in cylinder liner. The cylinder liner has an axis and a conical chamfer. The conical chamfer is in tangential contact with the double-curved surface in a seated position prior to any thermal expansion of the cylinder liner. In one related embodiment, the cylinder liner becomes slightly unseated from the seated position upon thermal expansion.

[0008] In another embodiment of the invention, the casting mold includes a second mold seat that has a double-curved surface in contact with the cylinder liner prior to any thermal expansion.

[0009] In yet another embodiment, the first and second mold seats have conical surfaces in contact with corresponding end surfaces of the cylinder liner, such that upon thermal expansion, the cylinder liner becomes slightly unseated from the seated position. The end surfaces of the cylinder liner may be conical or double-curved surfaces.

[0010] Other systems, methods, features and advantages of the invention will be or will become apparent to one with skill in the art upon examination of the following figures and detailed description. It is intended that all such additional systems, methods, features and advantages be included

within this description, be within the scope of the invention, and be protected by the accompanying claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] The present invention will become more fully understood from the detailed description and the accompanying drawings. The components in the figures are not necessarily to scale, emphasis instead being placed upon illustrating the principles of the invention. Moreover, in the figures, like reference numerals designate corresponding parts throughout the different views.

[0012] FIG. 1 is a sectional view of a partial mold package shown assembled on a temporary base;

[0013] FIG. 2a is a partial sectional view of an embodiment of a casting mold according to the present invention;

[0014] FIG. 2b is a partial sectional view of another embodiment of a casting mold according to the present invention;

[0015] FIG. 2c is a partial sectional view of another embodiment of a casting mold according to the present invention;

[0016] FIG. 3 is a partial sectional view of another embodiment of a casting mold according to the present invention;

[0017] FIG. 4 is an enlarged view of Detail D of FIG. 2a;

[0018] FIG. 5 is an enlarged view of Detail E of FIG. 2a;

[0019] FIG. 6 is a simplified diagram useful for illustrating an amount of axial unseating upon thermal expansion of a cylinder liner according to the present invention; and

[0020] FIG. 7 is cross-sectional views of the casting mold of the invention showing an amount of lateral unseating.

DETAILED DESCRIPTION OF VARIOUS EMBODIMENTS OF THE INVENTION

[0021] The following description of the preferred embodiments is merely exemplary in nature and is in no way intended to limit the invention, its application, or uses. Referring to the drawings, it is to be understood that standard components or features that are within the purview of an artisan of ordinary skill and do not contribute to the understanding of the various embodiments of the invention are omitted from the drawings to enhance clarity. In addition, it will be appreciated that the characterizations of various components and orientations described herein as being "vertical" or "horizontal" are relative characterizations only based upon the particular position or orientation of a given component for a particular application.

[0022] Referring to FIG. 2a, an embodiment of a casting mold 100 for an engine block is shown in partial section about an axis of symmetry denoted by "A", which coincides with the longitudinal axis of one of the cylinder bores of the engine block. It will be understood that the engine block includes one or many cylinder bores, for example eight bores for a V-8 engine, although for simplicity, the various embodiments of the invention are described in connection with a

single cylinder bore, without so limiting the invention. The casting mold 100 includes several mold parts, such as a slab core 102 and a barrel core 104. The mold parts are resin-bonded sand cores and can be made using conventional processes, such as a furan hot box or a phenolic urethane cold box core making process. Cores can be made using a variety of sands, such as silica, zircon, fused silica, etc. It will also be appreciated that the slab core 102 and the barrel core 104 may be each made as one integral piece or alternatively as a combination of smaller interconnected mold parts. A cast-in cylinder liner 106 is tightly confined between the slab core 102 and the barrel core 104. The cylinder liner 106 has a longitudinal axis "B" which coincides with the axis A when the cylinder liner 106 is aligned in the casting mold and there is no radial or axial displacement or tilting of axis B with respect to axis A, as shown in FIG. 2a. This position of the cylinder liner 106 is defined herein as the "seated position".

[0023] The cylinder liner 106 has a first end 108 adjacent to the slab core 102 and a second end 110 adjacent to the barrel core 104. In the embodiment shown in FIG. 2a, the first end 108 of the cylinder liner 106 is in contact with a first mold seat 112, which may be defined by a portion of the slab core 102. The first mold seat 112 has a convex double-curved surface 114, which is symmetric about the axis A and has two radii of curvature at each point. Such a surface is generated by revolving a curved line about the axis A, which is the axis of revolution or symmetry. Conical or cylindrical surfaces, which may be obtained when one radius goes to infinity, are single-curved surfaces. The

double-curved surface 114 of the first mold seat may be, for example, a portion of a sphere or torus.

[0024] The cylinder liner 106 contacts the surface 114 of first mold seat 112 along a contact circle 118. The contact circle 118 lies on a plane perpendicular to the axis A and has radius R_1. In one embodiment, the first end 108 of the cylinder liner includes a first end surface 116, which, in this embodiment, is a conical chamfer, as best seen in Detail D, FIG. 4. The chamfer 116 is tangent to the first mold seat surface 114 along the contact circle 118 and defines an angle α_1 with the plane of the contact circle 118, which is perpendicular to the axis A.

[0025] The second end 110 of the cylinder liner 106 is in contact with a second mold seat 120. The second mold seat 120 may contact the second end 110 at a conical surface 122, as shown in FIG. 2a, or at a double-curved surface 124, which is similar to the double-curved surface 114 of the first mold seat 112, as shown in FIG. 3. In the embodiment of FIG. 2a, the conical surface 122 is inclined at an angle α_2 with a plane perpendicular to the axis A, as best illustrated in Detail E, FIG. 5. The cylinder liner 106 may also include a second end surface 126, which, in this embodiment, is a conical chamfer having the same inclination α_2. In the embodiment of FIG. 3, the second chamfer 126 contacts the double-curved surface 124 of the second mold seat 120 tangentially at an angle α_2, which is defined by the second chamfer 126 and a plane perpendicular to the axis A. When the double-curved surfaces 114 and 124 of the first and second mold seats 112 and 120 are mirror images of each other, $\alpha_2 = \alpha_1 = \alpha$.

[0026] If all mold components are properly formed and assembled, in its initial state, before any heating resulting from the preheating process (if employed) or from the casting process, the cylinder liner 106 is seated on the first and second mold seats 112 and 120; that is the axis A of the bore coincides with the axis B of the cylinder liner 106, such that the cylinder liner 106 is not laterally displaced with respect to the axis of the bore A. The cylinder liner 106 is constrained by the first and second mold seats 112, 120. The angles α_1 and α_2 are selected such that the cylinder liner 106 will become "unseated", or no longer tightly confined by the first and second mold seats 112, 120, upon heating. Thus, the axis B of the cylinder liner 106 will become laterally displaced relative to the axis A by some amount, as shown in FIG. 7. An unseated cylinder liner 106 will be moved out of position by gravity, local adhesion of the cylinder liner to one or both of the seats 112, 120, or unbalanced metal pressure.

[0027] In other embodiments, shown in FIGS. 2b and 2c, the first mold seat 112 of FIG. 2a may be also configured to have a conical surface which is a mirror image of the conical surface 122 inclined at an angle $\alpha_1 = \alpha_2$ with a plane perpendicular to the axis A such that upon thermal expansion the cylinder liner 106 becomes unseated from the seated position on the first and second mold seats 112 and 120. The cylinder liner 106 has first and second end surfaces 116, 126 mating with the conical surfaces 114, 122 of the mold seats 112, 120. In the embodiment of FIG. 2b, the end surfaces 116, 126 are conical chamfers. In the embodiment of FIG. 2c, the end surfaces 116, 126 of the cylinder liner 106 are double-curved surfaces.

[0028] A small migration or misalignment of the axis B relative to the axis A during the preheating and/or casting processes is insignificant compared to the damage that may be caused if the cylinder liner 106 is constrained to be seated during these processes on the first and second mold seats 112, 120. According to the present teachings, unanticipated and/or unaccounted for thermal expansion of the cylinder liner 106 that differs from theory will be accommodated without pushing apart the seats and/or crushing or fracturing the seat material and contaminating the mold. Unanticipated and or unaccounted thermal expansion generally results from normal process variations in the actual dimensions and angles of the mold seats 112, 120 and the cylinder liner 106, as well as non-uniform thermal expansions during preheating and/or mold filling.

[0029] The undesirable consequences of unpredictable thermal expansion of the cylinder liner 106 are avoided in the present invention by designing the mold seats 112, 120 and the cylinder liner such that the cylinder liner becomes slightly unseated during thermal expansion. This is accomplished by allowing an amount of unconstrained expansion at one or both ends 108, 110 of the cylinder liner 106. In this regard, the chamfer angles α_1 and α_2 are selected to exceed the nominal values that are theoretically required for constrained seating by an amount that will not cause excessive unseating or misalignment of the cylinder liner 106. The nominal angles required for constant seating for the embodiments of FIGS. 2a, 2b and 3 are determined by the following equation:

[0030] $R_1 \times \tan \alpha_1 + R_2 \times \tan \alpha_2 = L$,

[0031] Where L is the length of the cylinder liner 106 determined at its contact with the mold seats 112, 120, and R_1 and R_2 are the corresponding radii at the contact with the mold seats. If $R_1 = R_2 = R$ and $\alpha_1 = \alpha_2 = \alpha$, then:

[0032] $\tan \alpha = L/2R$

[0033] As an example, consider a cast iron liner with R= 47.5 mm and L = 140 mm. For this cylinder liner, the nominal angle α for constrained seating is equal to 55.84°, and the coefficient of thermal expansion (k) is equal to 5.9×10^{-6}/°F. For a change in temperature of 1000°F, if α_1 and α_2 are chosen to be 10° higher than the nominal angle value, or 65.84°, the amount of axial unseating G_a may be calculated as follows. The change in length is ΔL:

[0034] $\Delta L = 1000 \times 5.9 \times 10^{-6} \times 140 = 0.826$ mm

[0035] The change in radius R is ΔR:

[0036] $\Delta R = 1000 \times 5.9 \times 10^{-6} \times 47.5 = 0.280$ mm

[0037] Referring to FIG. 6, the axial unseating G_a is measured from the tangents to the mold seats at the initial contact points:

[0038] $G_a = 2\, \Delta R \tan(65.84°) - \Delta L = 0.424$ mm.

[0039] Similarly, if only the first angle α_1 is increased by 10° to 65.84°, while the second angle α_2 is kept at the nominal value of 55.84°, the axial unseating G_a is:

[0040] $G_a = \Delta R \tan(65.84°) + \Delta R \tan(55.84°) - \Delta L = 0.212$ mm.

[0041] Therefore, for the cylinder liner of this example an increase of one of the chamfer angles by 10° causes the cylinder liner 106 to become axially

unseated only by 0.212 mm. An increase of both chamfer angles α_1 and α_2 by 10° causes the cylinder liner 106 to become axially unseated only by 0.424 mm.

[0042] The cylinder liner 106 is free to migrate laterally to the desired bore centerline as a result of G_a. Referring to FIG. 7, it can be shown that the lateral displacement G_L is equal to $(G_a/2)/\tan\alpha$. In the present example, if both angles are increased by 10°, this results in 0.095 mm of lateral migration.

[0043] It will be appreciated from these calculations that by increasing one or both chamfer angles α_1 and α_2 by as much as 10° from the nominal values that keep the cylinder liner 106 seated upon thermal expansion, only small radial or axial unseating of the cylinder liner 106 will occur, while many other advantages are realized in addition to preventing mold seat crushing or fracture. For example, the double-curved surface 114 reduces or eliminates scuffing of the mold seat 112 against the corner of the chamfer 116 of the cylinder liner 106. The increased chamfer angles α_1 or α_2 facilitate the insertion of mold seat 102 into the cylinder liner 106 during assembly of the mold 100, such that the cylinder liner 106 can be correctly assembled, especially in the case of V-type engines where the cylinder liners 106 are typically not vertical at the time the mold is assembled, as illustrated in FIG. 1, in which the mold package 40 is supported on a temporary base 50.

[0044] Greater chamfer angles α_1 and α_2 result in a smaller amount of lateral displacement G_L for a given amount of axial unseating G_a. Smaller lateral displacement G_L helps provide better control of any cylinder liners 106 which are unseated following mold assembly because of dimensional imperfections in the

slab core 102, barrel core 104 and cylinder liners 106 when the casting mold 100 is assembled.

[0045] While various embodiments of the invention have been described, it will be apparent to those of ordinary skill in the art that other embodiments and implementations are possible that are within the scope of this invention. Accordingly, the invention is not restricted except in light of the attached claims and their equivalents.